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ABSTRACT

The author proposes a model for futuristic studies which recognizes the interaction of the educational, social, and economic sectors. The hypothesis is that the relevance of education to social needs is lacking. An explanation for this lack of relevance is that futures forecasting tends to limit itself to only one sector of society, ignoring mutually interactive repercussions. The proposed integrated conceptual framework begins with the total population as the base. A portion of the base is involved in the educational system and a larger portion in the socio-economic sphere. The model is designed to illustrate the framework represented by a series of four overlapping circles representing the educational system, educational policies, social and economic policies, and socioeconomic activities. The model works according to a four step process: (1) a future scenario for socioeconomic activities results in the formation of policies; (2) these policies, when implemented, affect the population base through the socioeconomic sector and through educational policies designed to monitor the educational system; (3) the population responds to the changes positively by increasing production, or negatively, by decreasing it; and (4) the interactive portions of the separate sectors constantly monitor the system. The conclusion is that this framework can provide strategic guidelines for evolving appropriate educational reforms congruent to emerging life styles. (Author/KC)

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CHANGING GLOBAL SCENARIOS : IMPLICATIONS FOR EDUCATION

by

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The aims of APEID are:

- to stimulate efforts of the Member States to improve the quality of life of the people through creating and strengthening national capabilities for the development and implementation of innovations in education, both formal and non-formal;
- to encourage the Member States to make all groups (students, teachers, parents, village and community leaders, administrative personnel and policy makers) aware of the need for relevant changes in education (both formal and non-formal) as an essential pre-requisite for the improvement of the quality of life of the people;
- to promote understanding and appreciation of the differences in educational practices and approaches of the Member States, and thereby contribute to international understanding and the creation of a new international economic order.

CHANGING GLOBAL SCENARIOS : IMPLICATIONS FOR EDUCATION

by

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1. Introduction:

Extreme changes, whether purposively designed or unanticipated, are expected to dominate the international scene in the ensuing decades. The acquisition of a growing degree of dynamism by the hitherto sterile educational system constitutes, perhaps, one of the most potent components of the emerging era. The system is expected to be vested, increasingly, with responsibilities to create conditions for smoothly ushering in the unfolding pattern, while adapting itself simultaneously to such changes. What then, are the consequences of such crisscrossing interactive processes on the content, structure and function of the educational complex? The question acquires a sense of immediacy, as currently, education is at best viewed as a socially tolerable budget head for purposes of public expenditure. This note outlines a method to tract such an interactive process analytically. It also provides some clues towards using the proposed method in response to changing conditions, so that meaningful policy mixes could be determined.

2. The present crisis in the educational system:

Since educational expenditures are becoming increasingly socially accountable, it is expected to fulfil a social purpose. It is meant to act as an engine of social transformation, and is to be utilized as a reinforcing factor for the social fabric in the developmental process. This, however, is a far cry from the status it hitherto possessed in the restricted elitist preserves of society. The concept of equal opportunity has opened the portals of higher education to all, and in some parts made primary education a compulsory and compulsive acquisition. This is fortified by the attractive professional and social opportunities that beckon the successful condidates. This becomes somewhat incongruous though, when juxtaposed against the exhortations to make education more job-oriented. Obviously, it is not already so. Why then is a formal education insisted upon for selection to jobs?

A commonly advanced argument is that the educational process highlights, though it may not invest, a general ability of the individual to perform under different situations. However, educationists would not claim that the enhancement of the candidate's general attributes as well as those specifically required for a job, save for certain routine operative skills, to be - or at any rate, the most important - the goal

of education. This is understandable since education has grown up essentially as an attempt at understanding the being and becoming of phenomena, through a series of speculative processes. No wonder its relevance to society is found wanting.1/ Indeed the swelling numbers of unemployed and misfits in jobs testify that formal education is just a so-many-year-hurdle-race.

By broadening the base of such a system and improving the access to and delivery of educational services, we are putting more on the race-track, reducing the relative values of those that got ahead. The better became worse off as more of the worst joined them.2/ The real economic implication of this process is a net resource drain by toughening the race for those who have an easy access to 'quality' education in developed countries. In those countries where the resources are lacking to improve the quality of the educational process, it is a question of relative skills; picking the best among the worst. Since the latter system aims at converging to the former, there would only be a greater drain on resources.

Why is there such a cynicism about the content of education? This is so, because beyond the primary stage of education where the three 'Rs' are taught, the rest of the obstacle race is one long process of abstraction where one hypothesis is constructed after another, to be disproved at the next stage. Apart from the emphasis on the speculative factors - sometimes not even specifiable - there is a general negligence to inculcate the structuralist view. This induces a sheer disbelief in the student, who is better off if he forgets the most of it before he applies for a job, with any intention of being successful in it. This method of education involves the pupil in a process of mental skulduggery which keeps him off, by using the best part of his youth in trying to learn by rote what he fails to remember by reason.

This, however, is not to denigrate the implicit value of education. Basic needs programmes have highlighted the need for non-formal education which aims at functional literacy for all at various levels - at the work place, in the family, at the community level, through various human and mechanical teaching aids. The approach goes further; when extended to all other spheres of socio-economic activity, it is quite sceptical whether the present educational system is adequate to sustain the strain of even bearing, leave alone engineering, such wide-sweeping changes.

1/ Indeed the crisis has deepened further. The logical foundations too have been found to be wobbly. Concluding an essay on the concept of modern mathematics, a leading authority has recently said: "Gauss called mathematics the Queen of sciences. I prefer to call it Emperor, although it may yet transpire that the Emperor has no clothes; even so he is better dressed than his courtiers!" See Stewart, Ian. Concept of modern mathematics. Pelican, 1976.

2/ For a detailed discussion of such conflicts between social and individual benefits, see Hirsch, Fred. Social limits to growth. Cambridge, Mass., Harvard University Press, 1976. Annex I of this paper summarizes the salient features.

3. Future scenarios : the predictive process:

In general, the basic methodology adopted, while casting future scenarios for public services like education and health, involves the fixing of a time horizon, by which a certain normative level of the service is to be attained. Policy manoeuvres to reach this goal are formulated, which are then integrated to obtain a global picture.3/ As an alternative method, models of extrapolation are constructed for the economic sectors, and consistency tests are performed. Both these methods ignore the significant mutually interactive repercussions which would get intensified, specially over the long period. For example, while projecting a mass employment programme, the current educational system should be taken into account, and consideration should be given to the fact as to whether, at the policy-making stage, the system should be changed to cater to the employment needs, or only create such employment opportunities that can be met by the current system. In the absence of such a continuous dynamic adjustment of parameters, the future scenario is bound to be fuzzy, both in planning and execution. The method of merely extrapolating potential employment figures on the basis of additional projects does not help either.

In an attempt to improve the accuracy of predicted scenarios, controlled experiments on a small select portion of the actual population are conducted, so as to measure the potential effects of new social policies and programmes with a view to generalizing the results for futuristic studies. A case in point is the group of experiments for the programme for integrated rural development undertaken in various parts of the globe. Though the motivation is laudable and the experiment could be useful for forecasting, researchers face severe accuracy hazards while conducting them and generalizing the conclusions. At the very beginning, selection of the surface for experimentation, the combination of tests, etc., have to be based on a conceptual framework of several sets of alternative assumptions which could well nullify the experiment or predetermine the answer.4/ The responses to the various experiments are also affected by the socio-economic composition of each selected group. Other operational problems that arise are: whether the sample is representative or not; the conditioning of the response by the nature of the experiment itself; and the individual conduct in the social setting. Apart from the limitations imposed by the manner of their administration, the unpredictability of human response calls for more methodical research into the nature of the experimentation technique.

The same pitfalls befall the futuristic studies as well. The simplest form is one where there is a rigid extrapolation of the present economic structure. This input-output method excludes not only the significant economic forces which keep changing, but does not even touch the fringe of such social changes arising out of, say, increased

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3/ See Formulating strategies for health for all by the year 2000. Geneva, World Health Organization, 1979. See also Annex II for details.

4/ Ferber, Robert and Werner Z. Hirsch. "Social experimentation and economic policy : a survey," The Journal of Economic Literature, December 1978.

urbanization, women's participation, compulsory education and its effect on employment. The model is, nevertheless, by virtue of its balance mechanism, useful for short-term forecasting for demand or supply quantum of commodities. Another more sophisticated approach is to employ econometric models which are large-scale versions of micro-studies running into as many equations as the computers can handle. The simplest among these economic forecasts would be that of the trend scenario.5/ On the assumption of a 'reasonable' rate of increase, say, in food production and a slowing down of the population growth, demand and supply trends are projected for food. The study is undertaken for different commodities like cereals, milk, etc. Given the actual present production, the date when a certain degree of self-sufficiency will be achieved is then predicted. It is needless to say that the more 'realistic' the assumptions, the nearer will the sooth-sayer be to the mark.

In detailed forecast studies, no single model is used restrictively. Expert judgement combined with formal models together with consistency exercises are integrated to provide firm and reliable base-year data. Thus the supply and demand figures, as well as input requirement, resource-availability figures, are consistent with each other for each region which, when combined to form global strategies, calls for consistency in trade figures too. With this armada of statistics, scenarios are forecast for varying assumptions, and the income employment growth effects are predicted.

What has been bypassed in all these futuristic studies is the attention which needs to be paid to the effects of these projected variations on other sectors like education, or even an integration of the projections of various sectors; or yet, which is even more important, the allowance of flexibility to incorporate the intrinsic parametric variations in an interdependent set-up. In fact, the entire range of futuristic studies are for individual sectors separately with consistency tests 'within' the sector. However, the basic needs approach has placed an enormous burden on education by marking it as a key motivating sector towards the fulfilment of goals of the other sectors. This obviously calls for a structural conceptualization which can take into account intertemporal mutually reinforcing parametric variations iteratively.

4. The model:

Social challenges are shaping education in the form of revised syllabi and experimentation on the campus. Social control and accountability has made it necessary to conduct quantitative researches on various aspects of education and public policy so as to throw light on a range of problems such as attractiveness of higher education and the related subsidies for undergraduate courses, contribution of women to the academic field, benefit-cost analysis of vocational rehabilitation programmes, and other areas of manpower planning and human capital. However, all these partial prongs, in a macro set-up, aim at influencing the size structure and quality of population. Similarly, population, or the implicit human capital, determines the productivity in economic activity and the compatible design of the educational system. For an integrated conceptual framework, we could therefore begin with the total population

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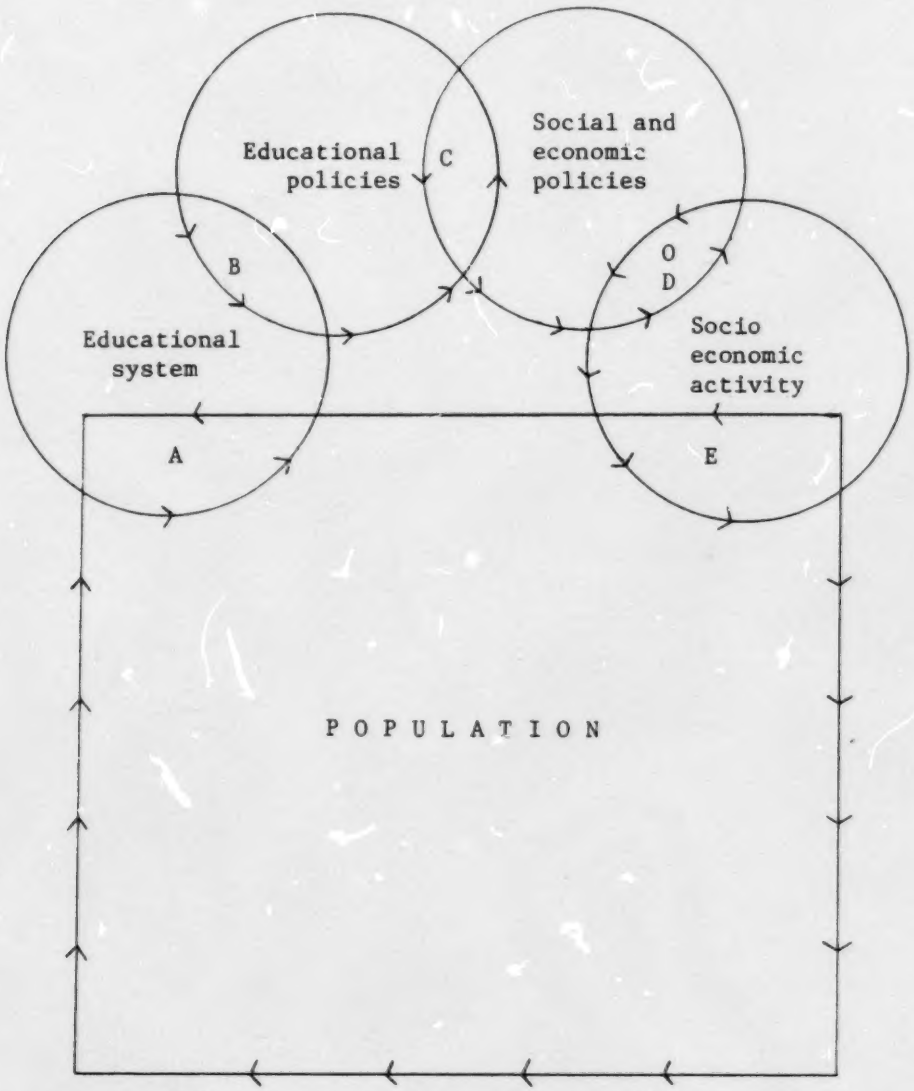
5/ Agriculture toward 2000 : regional implications with special reference to the Third Development Decade. FAO, 1979. See Annex III for a step-by-step description of the procedure.

as the base, of which a part is involved directly as teacher or taught in the educational system, and another substantial portion is involved actively in the socio-economic sphere. In order to highlight the effects on the educational system, it is separated from the economic structure, though the interdependence is retained through the interactive influence of educational and socio-economic policies. The following figure captures this mechanism.



In the context of projecting scenarios, the mechanism works as follows.6/ A future scenario for the socio-economic activity gives rise to a set of socio-economic policies whose aim is to engineer such projections into actuality. These policies, when implemented, affect the

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6/ In the diagram, the movement of the mechanism is marked clockwise as population in the motivating factor. For futuristic projections, however, studies concentrate on the economic activity. The subsequent mechanism is accordingly described anti-clockwise.

population base, both through the socio-economic layer directly and through the educational policies which are incorporated to monitor the educational system. The human capital potential of the population responds to these changes. If they are favourable policies, the effect is perceived through a stepped-up level of socio-economic activity which would then make the projected scenario a reality. If, however, either the socio-economic policies themselves, or the educational reforms are unfavourable, productivity of the population would be negatively affected. The areas represented by A, B, C, D and E in the figure are the sensitive inter-active surfaces which provide the clues to any fault in the mechanism, thus providing control and monitor points to the entire model. Dynamically the process of iteration would enable the policy maker to suitably manipulate these sensitized portions, not only to achieve goals, but also predict consistent and realistic scenarios. Policy mixes could be determined at each level, and the degree of intensity with which they are to be operated too could be outlined by adopting at each stage the changed impact, on each sector, of the previous parametric variations.

5. Conclusion:

The framework sketched above can be empirically articulated,[7/] both for policy implementation as well as to determine the effects of forecasting at different levels. Alternative scenarios can be worked out to provide a macro-economic framework which can assess meaningfully how each aspect affects the other, and not only explore the consequences, but also determine the degree of intensity for policy implementation. While the framework can comprehend the mutually interdependent effects of education and other sectors, its iterative mechanism can grapple with the consequences of the necessary educational reforms which can be evolved at each stage through fruitful social monitoring systems. It may thus, when worked out in detail, provide strategic guidelines towards evolving appropriate educational reforms for the emerging life-styles.

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7/ For the necessary mathematical scaffolding for such an exercise, see Bharadwaj, R. "A theorem on the problem of implementing a central strategy in a decentralised model," Indian Economic Journal October-December, 1974. The main result is reproduced as Annex IV.

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ANNEX I

Fred Hirsch on the Conflicts between Social and Individual Benefits

In his highly perspicuous work, *Social Limits to Growth*, Hirsch has eloquently drawn insights into the complex working of the process of economic growth. He has drawn pointed attention to the issues of production, of individual versus collective provision, and of distribution as being intertwined, leading to ambiguity and sometimes conflict between the motivation of individual actions and their collective result. This has rendered the traditional framework of analysis quite obsolete and incapable of handling the structural problems involved in the 'paradox of affluence', 'the distributional compulsion' and 'the reluctant collectivism'.

The satisfaction which individuals derive from the consumption of goods and services is increasingly assuming a social tinge. This is easily appreciated in the case of a public good such as clean air, as against the purely personal satisfaction derived from a meal eaten to overcome one's own hunger. However, the satisfaction from every consumption is affected by the utility the same good or service has to others. For example, as more people attain a certain level of education, the utility of expenditure on that as a means to secure jobs will decline. If everyone stands on tiptoe, no one sees better; yet, progress in society is to move ahead of others relatively. Unless there is a mutual agreement, competition will result in dead-weight costs leading to social waste. As the compulsion for better distribution increases the range of "buyers" and crowds out those already there, the key to personal welfare would again be to stay ahead of the others. Thus, affluence brings in its own frustration - a conflict of the individual and social motivation and action. In the context of scarce resources, and with an optimistic view that the passage of time would satisfy all, stoicism and social co-operation are preached at the same time as individual action, freedom and competition are favoured. It is a game of 'beggar thy neighbour' for each individual, even though all cannot play it - a case of social limits to growth which is as important as, if not more important than, physical limits.

Societal advance seen as individual advance or collective advance has different repercussions. As far as growth is a question for merely providing more goods of the same quality, those in the middle class of the society can continue their relative competitiveness. However, due to the new liberalism of the economic and political process, the impetus to universal participation makes the individual striving for excellence in terms of prizes, service, leadership quite a paradox, and ultimately a more difficult process - in the general race for survival, the fittest has to be a Superman to survive at all! Thus, the other extreme of the anomaly results wherein even to get individual benefits one has to resort to collective action as witnessed by the trend in trade unions.

When every reform in society is targeted towards levelling up the various social strata, positional competition is a dominant feature where one's reward is the position on the strata whose very structure presents levelling. Internal individual motivation for a better life is required to make collective action feasible as a law-abiding nature, and a moral - religious or ethical - code towards oneself and one's fellow being; yet mere individual motivation is insufficient, say to remove inequality or attain other social goals, though it may help towards the formulation and implementation of collective policies which would help to achieve harmony between individual and social benefits so that one does not end up collectively with a situation, which initially each individual tried to avoid.

"The disease, in brief " concludes Hirsch " is the blight on individual action as an effective means to individually desired results. The antibody, collective action, has costs and adverse side effects of its own. Accordingly, there is a premium on any corrective that avoids or minimizes this countervailing damage." Had not death snatched him prematurely, Hirsch's razor-sharp analysis would have undoubtedly won him that premium.

ANNEX II

WHO on Formulating Strategies for Health for all by the Year 2000

In order to implement the basic principle of an acceptable level of health for all by the year 2000, health, social and economic sectors have to operate in a supportive manner through the aid of individual, communal, national and international action. The principles of primary health care declared at Alma-Ata is the guiding force relating the policies of the Member States to that of the World Health Organization.

Briefly the main issues involved in formulating national policies, strategies and plans of action are as follows. In the context of general political and social matters, various essential processes and mechanisms are charted out with prominence to primary health care and with importance given to monitoring and evaluation. However, these are not mutually exclusive compartments, but a continuum with each country getting on to the process of achieving the target of health at any point convenient to it.

Each country would have to specify its own health goals following an identification and evaluation of problems and its capacity and, in consonance with its general socio-economic structure, formulate national health policies. Assuming that there is unequivocal political commitment to the objective of health for all, national strategies of specific health system supports should be adopted along with complementary action from other sectors such as education, agriculture, housing, industry and public service departments. The overall social goal of health for all has to be broken down into social policies aimed at the improvement of the quality of life and maximum health benefits for all. The national plans of action would of course consider the financial implications of such programmes and evolve suitable administrative reforms to arouse community participation so that health services are delivered efficiently on a country-wide basis. Though the entire programme is a long-term process, it is useful to prepare rough timetables, so that in the absence of time-precision, at least short-term and long-term measures can be identified and dovetailed into a consistent action. The time aspect becomes more important when designing the health system so that its various levels are co-ordinated in terms of the services, institutions and people. Country health programming measures could be incorporated within a systematic national planning process including defining priorities, modifying existing plans and formulating new ones as part of a continuing cycle. This naturally needs complex health information systems, specific to each country and internationally compatible.

Regional strategies, arrived at through the collective decision of the countries in each region, include well-defined objectives, related targets in the context of the national policies and strategies, with supporting inter-country mechanisms and arrangements. A global strategy is then arrived at through the collective decisions of the countries of the world in the World Health Assembly, and involves the adoption of global health policies through suitably strengthened bodies to achieve

health for all by the year 2000. In order to attract bilateral and multilateral funds and to ensure that they are channelized to proper priorities, estimates of the total resources for health development are made. A co-operative effort towards overcoming obstacles, exchanging information and technical expertise and global orientation and support for research is required. A global evaluation framework would then have to be evolved which would help monitor and evaluate world-wide efforts and its impact on attaining health for all by the year 2000.

ANNEX III

FAO on Agriculture: Toward 2000

The mainline methodology of "Agriculture Toward 2000" seeks to describe long-term global agricultural developments in detailed country, product and input terms, to support policy analysis at various levels of aggregation. The study is based on FAO's in-house estimation procedures; knowledge and data including that of agricultural production technology, experience in commodity demand and supply projections, and country studies and statistics.

Analytically, the aim is to prepare for each country (1) Supply Utilization Accounts, indicating the source (domestic or external) of supply and demand for 27 commodities; and (2) Input Requirements Accounts showing the crop-by-crop utilization of key agricultural and non-agricultural inputs including various types of land. These accounts have to be consistent both internally and globally with the availability of resources. A step-by-step description of the procedure follows:

"The methodology of AT 2000 has been designed to support the analysis of alternative development scenarios. To date, two have been studied. One of these has assumed the continuation of past global trends in income growth and agricultural production; the other, the study's preferred (normative) alternative, has set normative targets for accelerated general and agricultural growth in developing countries. Both scenarios make specific assumptions about future GDP and population levels. The normative scenario focuses on increasing food self-sufficiency in developing countries and also makes explicit assumptions about trading relations between developed and developing countries, and about resources (mainly land by various classes) available to agriculture. These assumptions ultimately determine demand, production trade and input requirements levels for each country. The description below indicates the main steps involved in the case of the normative scenario.

STEP 1. A Supply Utilization Accounting phase is first carried out country by country, and commodity by commodity. Given GDP and population projections, demands are projected for human consumption and industrial use. Intermediate and other non-final uses of agricultural products (feed, seed, waste) are next calculated. Preliminary projections, reflecting scenario objectives are now introduced to specify either production or trade levels. National supply-demand are then established by calculating either production or trade, whichever of the two was not directly projected (depending on the particular scenario to be simulated).

STEP 2. The input implications of the preliminary production targets are analysed in two parts. First, detailed yield projections together with land availability projections are developed by a team of experts. Their deliberations include a comprehensive, crop-specific review of each country's historical record and development potential.

Second, formal models are used to 'unfold' the implications of the production targets, as determined in step 1, for all inputs, including land, fertilizer, seeds, labour, tractors, etc. and assuming normal, i.e., average weather conditions.

STEP 3. The input and trade results of steps 1 and 2 are then re-examined from the perspectives of national resource availability and international consistency. If incompatibilities appear in either dimension, modifications are made to some or all of the building blocks of the projection, including the targets for production or trade, the projections for land availability, yields, and occasionally even demand. An effort is made to minimize departures from the normative production and demand targets specified in step 1. Thus land availability and yields are increased whenever such increases are still plausible, and a combination of strong demand and availability of non-land inputs which are not formally constrained permits more intensive cultivation. If production cannot satisfy demand even after these first revisions, import requirements are increased and sometimes demand projections reduced. Given these modifications, a new complete pass is made through all steps. Iterations continue until the checks performed in step 3 reveal no further inconsistencies.

ANNEX IV

On the Stability of Interactive Systems

The basic analytical question involved in articulating the framework of this paper for purposes of policy would be to examine whether large-scale representable realistic systems subjected to planned or unforseen changes, possess any inherently tractable features. Stated formally, such a problem could be seen as an exercise in examining the stability properties of a given structure allowing for arbitrary changes, over time in the coefficient matrices.

Thus, given a system

$$\dot{X}(t) = PX(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\dot{X}(t)$ is an n victor, P is an (n x n) matrix of coefficients and dots denote derivatives with respect to time.

Let the elements of P experience arbitrary variations following some policy moves. Denote the changed P matrix as Q. Then the system (1) may be denoted as:

$$\dot{Y}(t) = QY(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

with the same initial condition, i.e. $X(o) = Y(o)$

The problem is to examine whether systems (1) and (2) have the same asymptotic stability properties. Our result is embodied in the following :

*Theorem** : The real parts of the characteristic roots of Q will have the same sign as the real parts of the characteristic roots of P.

Proof : We know that X(t) and Y(t) are non-negative for all t. Further, the matrices P and Q on which the usual norm, given by $\left(\sum_{i}^{n} \sum_{j}^{n} \right)$, is defined would also be non-negative.

Let $\phi(z)$ be the characteristic polynomial of P. That is,

$$\phi_1(z) = P_{o1}^{n} + P_1 {}^{n-1} + \ldots \ldots \ldots \ldots + Pn \ldots \quad (3)$$

Where $P_0, P_1, \ldots\ldots\ldots$ Pn are functions of the elements of P. let $Q - P = E$ and let the elements of E be denoted by eij. We know that for systems such as (1) and (2)

$$|| E || < \varepsilon, \text{ where } \varepsilon \text{ is arbitrary}^{**}$$

The characteristic polynomial of Q depends on the elements of P and E. Let $\phi_{2E}(z)$ denote the characteristic polynomial of Q for a particular choice of E.

$$\phi_{2E}(z) = q_0 z^n + q_1 z^{n-1} + \ldots \quad \ldots \quad \ldots \quad \ldots + q_n \ldots (4)$$

The Co-efficients q_i in (4) depend on eij, the elemtns of E. Next, we define by $\phi_2(z)$, the following limit operation :

$$\phi_2(z) = \lim_{||E|| \to 0} \phi_{2E}(z) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

By the Cayley--Hamilton theorem, every matrix satisfies its own characteristic equation, so that

$$\left.\begin{aligned} &\phi_1(P) = O \\ \text{and} \quad &\phi_{2E}(Q) = O \text{ for all } E \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (6)$$

on substituting $Q = P + E$ in the second of the two equations in (6) we obtain

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** Bellman R.: Stability Theory of Differential Equations, Dover, New York 1969.

$$0 = \phi_{2E}(Q) = \phi_{2E}(P + E) = \phi_{2E}(P) + \overset{s-1}{q_0 P E} + \quad \dots \quad + q_0 E^s$$
$$+ q_1 P^{s-2} E + \quad \dots \quad \dots \quad q_1 E^{s-1}$$
$$+ \quad \dots \quad \dots \quad \dots \quad q_{s-1} E.$$

$$\therefore \phi_{2E}(Q) = \phi_{2E}(P) + E\,\Psi_{2E}(P, E) = 0 \quad \dots \quad \dots \quad \dots \quad (7)$$

where Ψ_{2E} is a polynomial in powers of P and E of degree $(n-1)$. Taking limits on both sides of (7) as $||\ E\ || \to 0$ we get,

$$\underset{||E||\to 0}{\text{Lim}}\,\phi_{2E}(Q) = \underset{||E||\to 0}{\text{Lim}}\,\phi_{2E}(P) + \underset{||E||\to 0}{\text{Lim}}\,E\,\Psi_{2E}(P, E) \quad \dots \quad \dots \quad (8)$$

The second member of the right hand side of (8) is zero and from (5), (6), (7) and (8) we obtain,

$$\phi_2(Q) = \phi_2(P) = 0 \quad \dots \quad \dots \quad (9)$$

and hence $\phi_1(P) = \phi_2(P) = 0 \quad \dots \quad (10)$

Thus the matrix functions $\phi_1(P)$ and $\phi_2(P)$ coincide. Hence, in view of Pontrijagin's famous theorem, $\phi_1(z)$ and $\phi_2(z)$, *coincide on the spectrum of the matrix P.*

The last statement implies the following*

$$\phi_1(\lambda_i) = \phi_2(\lambda_i) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (11)$$

and $\phi_1^{(j)}(\lambda_i) = \phi_2^{(j)}(\lambda i), \quad (j = 1, \quad \dots \quad \dots (k_i - 1) \dots \quad (12)$

where λi is an eigen root of P of multiplicity k_i and $\phi_1^{(j)}$, $\phi_2^{(j)}$ denote the j^{th} derivatives with respect to z of ϕ_1 and ϕ_2 respectively. (11) and (12) together imply that the limiting polynomial $\phi_2(Z)$ has the same roots as the polynomial $\phi_1(Z)$. Hence, if the i^{th} eigenroot λ_i of P has multiplicity k_i, Q will have k_i distinct roots all arbitrarily close to λ_i.

Thus, the sign of the real parts of the characteristic roots of Q will be the same as the sign of the real parts of the corresponding roots of P.

The system (2) thus, has the same asymptotic stability properties as the system (1). Q.E.D.

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* Pontriajin L.S.: A Course in Ordinary Differential Equations, Hindustan Publishing Co., New Delhi 1967.